DESCRIPTION

IMPROVEMENTS IN OR RELATING TO WIRELESS TERMINALS

Technical Field

The present invention relates to wireless terminal, for example a cellular telephone, having a dual-band antenna arrangement comprising a substantially planar patch antenna, and to a module incorporating such an arrangement. In the present specification, the term dual-band antenna relates to an antenna which functions satisfactorily in two (or more) separate frequency bands but not in the unused spectrum between the bands.

Background Art

Wireless terminals, such as mobile phone handsets, typically incorporate either an external antenna, such as a normal mode helix or meander line antenna, or an internal antenna, such as a Planar Inverted-F Antenna (PIFA) or similar.

Such antennas are small (relative to a wavelength) and therefore, owing to the fundamental limits of small antennas, narrowband. However, cellular radio communication systems typically have a fractional bandwidth of 10% or more. To achieve such a bandwidth from a PIFA for example requires a considerable volume, there being a direct relationship between the bandwidth of a patch antenna and its volume, but such a volume is not readily available with the current trends towards small handsets. Further, PIFAs become reactive at resonance as the patch height is increased, which is necessary to improve bandwidth.

US Patent Specification 6,061,024 discloses a duplexing antenna for a single band, for example 800 to 900 MHz, portable radio transceiver in which the antenna comprises respective PIFA transmit and receive antennas formed as patches on a printed circuit board mounted above and facing a reference ground plane of a circuit board on which the transmitter and receiver components are mounted. Separate feeds interconnect an output bandpass filter of the transmitter and an input bandpass filter of the receiver with their

respective patch antenna. An electrically conductive pedestal connects the reference ground plane to an elongate area of the printed circuit extending between the patches. Both the transmit and receive antennas are narrow band, say 1.6 MHz, antennas which are tunable over a wider bandwidth, say

5   25 MHz, by coupling reactive components, that is capacitances or inductances, to the respective antennas using PIN diode switches.

Our pending unpublished PCT Patent Application IB02/05031 (Applicant's reference PHGB 010194) discloses a wireless terminal having a dual band PIFA comprising a substantially planar patch conductor. A first feed

10   conductor comprises a first feed pin connected to the patch conductor at a first point, a second feed conductor comprises a second feed pin connected to the patch conductor at a second point, and a ground conductor comprises a ground pin connected between a third point on the patch conductor and a ground p lane. T he feed a nd g round p ins m ay h ave d ifferent c ross-sectional

15   areas to provide an impedance transformation. First and second transmission lines a re formed by t he g round c onductor and a r espective o ne of t he feed conductors. The first and second transmission lines are short circuit transmission lines whose respective lengths are defined by a first linking conductor connecting the first feed and ground pins and a second linking

20   conductor connecting the second feed and ground pins. Complementary circuit elements comprising first and second shunt capacitance means are coupled respectively between the first and second feed pins and the ground pin. The described antenna is fed by a diplexer to provide isolation between say GSM circuitry operating over a frequency band 880 to 960 MHz and DCS

25   circuitry operating over a frequency band of 1710 to 1880 MHz. The provision of a diplexer although enabling the cited antenna arrangement to work satisfactorily represents an undesired complication.

Disclosure of Invention

An object of the present invention is to simplify the architecture of a

30   wireless terminal.

According to a first aspect of the present invention there is provided a wireless terminal having a dual band antenna arrangement comprising an

antenna having a first feed for signals in a first, lower frequency band, a second feed for signals in a second, higher frequency band and a ground pin, first coupling means for coupling transmit and receive paths of a first transceiver to the first feed, second coupling means for coupling transmit and

5   receive paths of a second transceiver to the second feed, each of the first and second coupling means comprising a quarter wavelength transmission line having a first end coupled to the respective transmit signal path and a second end coupled by bandpass filtering means to the respective receive signal path, a first switching device coupling a transmit signal path to the first end of the

10   respective quarter wavelength transmission line, a second switching device coupling the second end of the respective quarter wavelength transmission line to ground, and means for switching-on the first and second switching devices of one of the first and second coupling means when in a transmit mode and for switching-off the first and second switching devices when in a

15   receive mode, the first and second switching devices of the other of the first and second coupling means being non-conductive.

According to a second aspect of the present invention there is provided an RF module for use with a dual band antenna arrangement, the RF module comprising a first antenna feed for signals in a first, lower frequency

20   band, a second antenna feed for signals in a second, higher frequency band and a ground pin, first coupling means for coupling transmit and receive paths of a first transceiver to the first feed, second coupling means for coupling transmit and receive paths of a second transceiver to the second feed, each of the first and second coupling means comprising a quarter wavelength

25   transmission line having a first end coupled to the respective transmit signal path and a second end coupled by bandpass filtering means to the respective receive signal path, a first switching device coupling a transmit signal path to the first end of the respective quarter wavelength transmission line, a second switching device coupling the second end of the respective quarter wavelength transmission line to ground, and means for switching-on the first and second

30   switching devices of one of the first and second coupling means when in a transmit mode and for switching-off the first and second switching devices

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when in a receive mode, the first and second switching devices of the other of the first and second coupling means being non-conductive.

According to a third aspect of the present invention there is provided a combination of a RF module made in accordance with the second aspect of the present invention and an antenna having means for connection to the first and second feeds and the ground pin.

The antenna may comprise a patch antenna such as a PIFA (planar inverted-F antenna).

The ground pin may be disposed between, and insulated from, the first and second feeds.

The first and second switching devices may comprise any suitable RF switching devices such as PIN diodes.

Brief Description of Drawings

The present invention will now be described, by way of example, with reference to the accompanying drawings, wherein:

Figure 1 is a block schematic diagram of an embodiment of a wireless terminal made in accordance with the present invention,

Figure 2 is a diagram of a circuit board having a PIFA and transmitting and receiving filters,

Figure 3 is a Smith chart showing the performance of the terminal in the GSM transmit mode,

Figure 4 is a graph showing the simulated return loss S_{11} in dB against frequency in GHz for the GSM transmit mode,

Figure 5 is a graph showing the total efficiency in the GSM transmit mode,

Figure 6 is a graph showing the GSM transmit out-of-band attenuation,

Figure 7 is a Smith chart showing the performance of the terminal in the DCS transmit mode,

Figure 8 is a graph showing the simulated return loss S_{11} in dB against frequency in GHz for the DCS transmit mode,

Figure 9 is a graph showing the total efficiency in the DCS transmit mode,

Figure 10 is a graph showing the DCS transmit out-of-band attenuation,

Figure 11 is a Smith chart showing the performance of the terminal in the DCS receive mode,

Figure 12 is a graph showing the simulated return loss S_{11} in dB against frequency in GHz for the DCS receive mode,

Figure 13 is a graph showing the total efficiency in the DCS receive mode,

Figure 14 is a Smith chart showing the performance of the terminal in the GSM receive mode,

Figure 15 is a graph showing the simulated return loss S_{11} in dB against frequency in GHz for the GSM receive mode, and

Figure 16 is a graph showing the total efficiency in the GSM receive mode.

In the drawings the same reference numerals have been used to indicate corresponding features.

Modes for Carrying Out the Invention

Referring to Figure 1, the wireless terminal comprises a PIFA antenna 10 having feeds 12 and 14 to which are connected a GSM transceiver which operates in a frequency band of 880 to 960 MHz and a DCS transceiver which operates in the frequency band 1710 to 1880 MHz, respectively. A ground pin 16 is provided between the feeds 12, 14 as shown in Figure 2 to be described later. As the architectures of the GSM and the DCS transceivers are generally the same the corresponding stages will be referenced with the suffices A and B respectively and in the interests of brevity only the GSM transceiver will be described. The transmitter section of the GSM transceiver comprises a signal input terminal 18A coupled to an input signal processing stage 20A. The stage 20A is coupled to a modulator 22A which provides a modulated signal to a transmitter stage 24A which includes a frequency up-converter, power amplifier and any relevant filters. A common coupling stage 26A couples the transmitter stage to the antenna feed 12. The common coupling stages 26A and 26B will be described in greater detail later. The coupling stage 26A is also coupled to a receiver section 28A of the GSM transceiver to the feed 10.

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The receiver section 28A includes a low noise amplifier, a frequency down-converter and filters. An output of the receiver section 28A is demodulated in a demodulator 30A and its output is applied to a signal processing stage 32A which provides an output signal on a terminal 34A. The operation of both of
5   the transceivers is controlled by a processor 36.

Referring to Figure 2, a printed circuit board PCB has components (not shown) on one side and a ground plane GP on the reverse side. A PIFA 10 is mounted on, or carried by, the PCB. The PIFA can be implemented in several alternative ways, for example as a preformed metal plate carried by the PCB
10   using posts of an insulating material, as a pre-etched piece of printed circuit board carried by the PCB, as a block of insulating material having the PIFA formed by selectively etching a conductive layer provided on the insulating material or by selectively printing a conductive layer on the insulating block or as an antenna on the cell phone case. For use at GSM and DCS frequencies,
15   the dimensions of the PIFA 10 are length (dimension "a") 40mm, height (dimension "b") 8mm and depth (dimension "c") 4mm. The planar conductor or conductive layer incorporates a slot 40 comprising four interconnected rectilinear sections 40A to 40D having an overall shape approximating to an inverted question mark without the dot. The section 40A which opens into the
20   top edge of the PIFA 10 is wider than the sections 40B to 40D which have substantially the same width. The slot 40 can be considered as dividing the planar conductor into two antennas connected to a common feed, namely a smaller central radiator R1 for the DCS frequency band and a longer radiator R2, wrapped around the central radiator R1, for the GSM frequency band.

25   The feeds 12, 14 are on either side of the ground pin 16 and the spaces between the feed and ground pins 12, 14, 16 have been partially filled with a conductive material 42 to leave unfilled gaps G1 and G2, each of the order of 2mm. The sizes of the gaps could be different on either side of the ground pin 16 in order to optimise independently each band. It can be seen that the feed
30   pin 12 for GSM is wider than the feed pin 14 in order that the common mode impedance transformation is different for both bands.

Other arrangements of the feed pins 12, 14 and the ground pin 16 to that shown in Figure 2 are possible. For example the ground pin 16 could be offset to one side of the feed pins 12, 14.

Due to the conductive material 42 partially filling the spaces between the respective feed pins 12, 14 and the ground pin 16, the PIFA incorporates a low valued shunt inductance across each feed. This inductance is tuned by shunt capacitors 46A, 46B (Figure 1) on each feed by resonating with it at the resonant frequency of the antenna. Since the feeds are independent, each capacitance can be independently optimised, resulting in more wide band performance for both bands with no compromise required between the two bands. In order to prevent energy from being transferred between the two feeds 12, 14, the antenna is co-designed with the RF front end by the provision of the common coupling stages 26A, 26B.

Reverting to the coupling stages 26A, 26B shown in Figure 1, apart from one difference in the stage 26B, the architectures of these stages is the same although the component values are selected for the particular frequencies of use and where appropriate the same reference numerals with the suffix A or B have been used to indicate corresponding components in the coupling stages 26A and 26B, respectively.

For convenience the coupling stage 26A will be described and the reference numerals of the corresponding components in the coupling stage 26B will be shown in parentheses. The output of the transmitting stage 24A (24B) is coupled to the anode of a low loss PIN diode D1 (D3), the cathode of which is coupled to one end of a series inductance 48A (48B). The other end of the inductance 48A (48B) is coupled to the feed 12 (14), to the shunt capacitor 46A (46B) and to one end of a quarter wavelength (λ/4) transmission line 50A (50B). The other end of the transmission line 50A (50B) is coupled to the anode of a low loss PIN diode D2 (D4), the cathode of which is coupled to ground, and to an input of a band pass filter 52A (52B). The filters 52A, 52B may comprise SAW filters. The output of the filter 52A (52B) is coupled to the input of the receiver section 28A (28B).

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If the filter 52B is implemented as a SAW filter, a RF resonant trap circuit 54 is provided in the signal path from the other end of the transmission line 50B to the input of the band pass filter 52B.The trap circuit comprises a series capacitor 56 and a shunt inductance 58 which is coupled to ground by
5   way of a capacitor 60. The value of the capacitor 60 is selected to tune the inductance 58 so that the voltage at the input to the filter 52B is reduced. Typically such SAW filters can handle in-band signals of up to a power of 13 dBm. However for out-of-band signals a higher power can be delivered to such a filter which is useful as a GSM signal can have a power of up to 30dBm. In
10   an alternative implementation BAW (Bulk Acoustic Wave) filters may be considered as they exhibit the same out-of-band impedance characteristics to resonant SAW devices and also they do not suffer from the power handling restrictions which apply to SAW filters.

The switching of the PIN diodes D1 to D4 is controlled by the processor
15   36 in accordance with the following truth table.

	D1	D2	D3	D4
GSM Tx	On	On	Off	Off
GSM Rx	Off	Off	Off	Off
DCS Tx	Off	Off	On	On
DCS Rx	Off	Off	Off	Off

In operation when the GSM transmitter is operating and the DCS transmitter is inactive, the PIN diodes D1, D2 are conductive so that the signal is applied to the feed 12. The other end of the transmission line is open circuit
20   with the result that the transmitted signal does not enter the receiver section 28A. A similar situation occurs when the DCS transmitter is operating and the PIN diodes D3, D4 are conductive.

When a GSM signal is being received the PIN diodes D1, D2 are non-conductive, as are the PIN diodes D3, D4. The received signal passes through
25   the transmission line 50A and is passed by the band pass filter 52A to the receiver section 28A. By the feeds 12 and 14 being on the opposite sides of the ground pin 16, the band pass filter 52B appears reflective to the GSM

signal thereby attenuating or blocking this signal. Any GSM signal which is present at the input to the band pass filter 52B will in any event be blocked by the filter. The converse is true when a DCS signal is being received by the receiver section 28B.

The dual feed allows independent optimisation and broad band operation in both the GSM and DCS bands. The integrated design of the antenna, matching circuitry and filtering allows a better overall match and efficiency with a simple architecture.

In assessing the performance of the PIFA and the associated coupling stages 26A, 26B, the following assumptions/simplifications have been made. The PIN diodes are represented by 2Ω series resistors in the "On" state and 0.25pF series capacitors in the "Off" state. The antenna efficiency is not included-all power in the antenna is assumed to be radiated. Ideal transmission lines 50A, 50B have been used. All components are assigned Q's of 50 (constant with frequency). This is regarded as being slightly optimistic for inductors and pessimistic for capacitors (dependent on technology, frequency and so forth).

The performance of the circuit shown in Figure 1 when operating in the GSM transmit mode is illustrated by in Figure 3 by a Smith chart and in Figure 4 by a graph showing the simulated return loss S_{11} in dB against frequency F in GHz. In Figures 3 and 4 the arrows GTX1 and GTX2 refer respectively to a frequency/attenuation of 880MHz/-20.205 dB and 915 MHz/-9.513dB. Here the antenna is slightly mismatched in order to achieve balanced edge efficiencies as shown in Figure 5 in which the arrow e1 indicates a frequency of 915 MHz and a total efficiency of 0.710 and the arrow e2 indicates a frequency of 880 MHz and a total efficiency of 0.659. The relatively low efficiency (65%) at 880MHz is due largely to the Q of the capacitor 46A (Figure 1) at the GSM input to the antenna. It is felt that this can be improved by using a better quality component and by better optimisation of the antenna impedance. Figure 6 illustrates the corresponding out-of-band attenuation (mostly provided by the antenna). The arrows G1, G2, G3 and G4 respectively represent the frequency/efficiencies of 880MHz/-1.812dB, 915MHz/-1.490dB, 1.785 GHz/-

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33.627dB and 2.640 GHz/-42.184dB. The combination of the antenna and the circuitry provides high levels of second (-33dB) and third (-42db) harmonic suppression.

In the DCS transmit mode the PIN diodes D1 and D2 are both "Off" while the PIN diodes D3 and D4 are "On". In this condition the GSM transmitter is isolated predominantly by the PIN diode D1. The GSM receiver SAW filter 52A is isolated predominantly by the antenna 10 being reflective. At the input of the GSM receiver SAW filter 52A the worst case isolation is approximately -26dB, giving a power of 4dBm. This is significantly less than the power rating of the SAW filter. The voltage developed is approximately 0.7V which is less than would occur in-band at the maximum power rating. Thus, in the GSM branch a resonant trap is not required.

The performance of the circuit shown in Figure 1 when operating in the DCS transmit mode is illustrated in Figure 7 by a Smith chart and in Figure 8 by a graph showing the simulated return loss S_{11} in dB against frequency F in GHz. In Figures 7 and 8 the arrows DTX1 and DTX2 refer respectively to a frequency/attenuation of 1.710GHz/-9.532dB and 1.785GHz/-13.782dB. Figure 9 illustrates optimising the simulated return loss S_{11} for efficiency. In Figure 9 the arrow e1 indicates a frequency of 1.795 GHz and a total efficiency of 0.823 and the arrow e2 indicates a frequency of 1.710 GHz and a total efficiency of 0.752. The corresponding out-of-band attenuation (mostly provided by the antenna) is shown in Figure 10. The arrows G1, G2, G3 and G4 respectively represent the frequency/efficiencies of 1.710GHz/-1.236dB, 1.795GHz/-0.844dB, 3.000 GHz/-24.540dB and 3.000 GHz/-24.540dB. It is anticipated that this configuration will provide reasonable levels of second or third harmonic suppression.

In the DCS receive mode all the PIN diodes are "Off". The performance of the circuit shown in Figure 1 when operating in the DCS receive mode is illustrated in Figure 11 by a Smith chart and in Figure 12 by a graph illustrating the simulated return loss S_{11} in dB against frequency F in GHz. In Figures 11 and 12 the arrows DRX1 and DRX2 refer respectively to a frequency/attenuation of 1.805 GHz/-12.743 dB and 1.880 GHz/-7.503 dB. The

DCS receive mode efficiency is shown in Figure 13. In Figure 13 the arrow e1 indicates a frequency of 1.805 GHz and a total efficiency of 0.405 and the arrow e2 indicates a frequency of 1.880 GHz and a total efficiency of 0.414. The worst case band edge loss in this mode is nearly 4dB. This is approximately 2dB higher than for a filter in a 50Ω system. The additional loss is primarily due to impedance mismatch presented by the antenna and seems sensitive to the impedance (for example, whether the antenna presents an inductive or capacitive load). In a conventional antenna system this mechanism is expected to give significantly more additional loss.

The performance of the circuit shown in Figure 1 when operating in the GSM receive mode is illustrated in Figure 14 by a Smith chart and in Figure 15 by a graph illustrating the simulated return loss S_{11} in dB against frequency F in GHz. In Figures 14 and 15 the arrows referenced GRX1 and GRX2 refer respectively to frequencies/attenuations of 925 MHz/-11.298 and 960 MHz/-11.578. Figure 16 shows the GSM receive mode efficiency, the arrow e1 indicates a frequency of 925 MHz and a total efficiency of 0.496 and the arrow e2 indicates a frequency of 960 MHz and a total efficiency if 0.478.

The performance of the circuit illustrated in Figure 1 is regarded as being superior to the of a conventional configuration using a diplexer in the following areas:

(1) The total efficiency (including the effects of antenna mismatch) is greater.

(2) The match at the power amplifiers and low noise amplifiers is improved.

(3) The antenna and associated circuitry provide a high degree of harmonic filtering. the filtering requirements of the rest of the module can be reduced if this is taken into consideration.

Points (1) and (2) are regarded as being particularly important. If an RF module is designed without consideration of the antenna, the input match and efficiency will be poor when connected to a typical antenna. Since the RF is contained within the module, there is no opportunity to counter the effects of the antenna at intermediate circuit stages.

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Although the present invention has been described with reference to a wireless terminal having a PIFA antenna and operating in the GSM and DCS bands. The invention may be applied to any multiband radio and in other dual band applications. Also the present invention relates to an RF module having

5   an antenna and at least those components included in the coupling stages 26A and 26B.

In the present specification and claims the word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. Further, the word "comprising" does not exclude the presence of other elements or steps

10   than those listed.

From reading the present disclosure, other modifications will be apparent to persons skilled in the art. Such modifications may involve other features which are already known in the design, manufacture and use of wireless terminals and component parts therefor and which may be used

15   instead of or in addition to features already described herein.

Industrial Applicability

Multiband Wireless terminals, for example dual band mobile telephones.